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On the Images formed by a Parabolic Mirror. Second Paper: Influence on the Measurement and Reduction of a Photograph.

By H. C. Plummer, M.A.

1. The relative merits of the mirror and the objective corrected for photographic rays were keenly debated at the first conference of the Astrographic Chart Committee. The wisdom of the decision to reject the reflector for the purpose in view has not, and need not, be questioned. On the other hand, the value of the instrument for certain branches of work cannot be denied, and it is probable that the reflector will be used in the future even more extensively than at present. Already a large store of photographs has been accumulated, and it is important to ascertain how far precise results can be obtained from them. At present there seems to be little material for estimating the degree of accuracy with which reflector photographs can be measured. Though confessedly imperfect in certain directions, this note seems to show that very accurate results cannot be expected from the measurement of at least one important class of photographs of this kind.

2. In accordance with a suggestion by Professor Turner a direct comparison has been made between a photograph taken with a parabolic reflector and a plate taken at the University Observatory, Oxford, for the purpose of the Astrographic Chart Catalogue. The work gave rise to a geometrical study of the aberration of the mirror, the results of which have been given in a former paper.* A photograph of the region containing the nebula H V 15 *Cygni* was taken by Dr. Isaac Roberts on 1896 October 10 with an exposure of $2^h\ 18^m$, the instrument employed being his parabolic mirror of 20-inch aperture and 98-inch focal length. The region is practically coincident with that covered by a plate already taken at Oxford for the Astrographic Catalogue. In response to a request for a copy of his photograph, Dr. Roberts very kindly sent to the University Observatory a glass positive. A contact print of this copy was made on another plate, on which a réseau was also impressed. This final copy will be designated Plate A, and it is evident that, as a representation of the sky, it must be considered inferior to the original negative. Not only is the risk of distortion of the film introduced in the process of developing unréseaued plates, but the danger arising from want of perfect contact between the plates in the process of copying † has also to be borne in mind, especially when, as in this case, neither the original negative nor the intermediate positive is on plate glass. It is clear then that the material used in the discussion is drawn from a source which may be distinctly inferior to the original photograph, but the

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* *Monthly Notices*, vol. lxii. p. 352.

† Cf. *Monthly Notices*, vol. lix. p. 462.

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opinion may be confidently expressed that the difficulties which do present themselves in the consideration of the measures are certainly not due in any great degree to effects arising from this fact.

3. With the Plate A is to be compared the Oxford plate 1571 taken by Mr. Bellamy on 1900 August 22. It bears three exposures of 6 minutes, 3 minutes, and 1 minute respectively, and the approximate position of the plate centre is R.A. $20^h\ 42^m$, Decl. $+30°$. This plate will henceforth be designated Plate B. The positions of the longest exposures had been measured by Mr. H. F. Mullis in the case of those stars, 872 in number, which showed three images. Apparently the centres of both plates are so nearly the same that the measures in the two cases may be directly connected by means of linear formulæ. Now if x_1, y_1 are the coordinates of a star on Plate A (referred to the corner of the réseau as origin) and x_2, y_2 the coordinates of the same star on Plate B, it is found by identifying four particular stars on both plates that if

$$x'_2 = -0{\cdot}727\ x_2 + 0{\cdot}010\ y_2 + 22{\cdot}040$$
$$x'_2 = +0{\cdot}010\ x_2 + 0{\cdot}727\ y_2 + \ \ 1{\cdot}420$$

then x'_2, y'_2 do not differ greatly from x_1, y_1. The transformation indicates (1) a reversal due to the fact that one photograph is taken with a reflector, the other with a refractor; (2) a change of scale due to the fact that the focal lengths of the two telescopes are in the ratio of 8 : 11 very nearly; (3) changes of orientation and of origin which are without any importance because they depend entirely on the way in which the glass positive and the réseau were placed in the making of Plate A.

4. The region common to the two plates A and B contains sixty stars which are to be found either in the Cambridge or the Leiden zones of the A.G. Catalogue. By adopting Plate B as a standard for direct comparison, we are independent of the catalogue places of these stars. Nevertheless the direct reduction of Plate A would be based on these stars, and it is therefore interesting to confine the comparison in the first instance to their coordinates. Accordingly, x'_2, y'_2 were calculated from the measures on Plate B, and x_1, y_1 were measured on Plate A. The constants of the linear formulæ

$$ax_1 + by_1 + c = x_1 - x'_2$$
$$dx_1 + ey_1 + f = y_1 - y'_2$$

were then calculated by Mr. Dyson's method,* the use of which is warranted by the number of stars. The resulting values are:

$$a = +0{\cdot}00134\,; \qquad d = +0{\cdot}00097$$
$$b = -0{\cdot}00049\,; \qquad e = +0{\cdot}00165$$
$$c = -0{\cdot}0350\ \ ; \qquad f = -0{\cdot}0334$$

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* *Monthly Notices*, vol. lv. p. 61.

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The fifth and sixth columns of the following table give the residuals derived from this solution in the sense

$$\delta x = x_1 - x'_2 - (ax_1 + by_1 + c)$$
$$\delta y = y_1 - y'_2 - (dx_1 + ey_1 + f)$$

The scale is such that $\cdot 001 = 0''\cdot 4$ nearly. The stars whose numbers, given in the first column, lie between 11000 and 12000 are to be found in the Cambridge zones; those whose numbers lie between 8000 and 9000 belong to the Leiden zones. The third and fourth columns contain my own measures on Plate A.

TABLE I.

Cat. No.	Mag.	x_1	y_1	δx	δy	(δx)	(δy)
11640	9·5	20·444	4·718	−·001	+·001	−·002	−·001
11654	,,	19·010	8·755	−·001	·000	−·001	·000
11691	,,	15·734	5·285	·000	−·001	+·003	+·001
11714	,,	14·107	12·760	·000	−·003	+·003	−·001
11718	,,	13·600	12·572	·000	·000	+·003	−·001
11751	,,	10·504	10·067	−·005	·000	−·001	−·002
11787	,,	7·990	6·625	−·001	− 003	−·004	−·003
11650	9·4	19·910	9·086	−·003	·000	·000	−·003
11676	,,	16·361	6·744	·000	+·001	·000	+·004
11689	,,	15·923	13·514	+·003	+·003	+·002	−·002
11753	,,	10·000	4·946	+·004	−·003	+·003	+·003
11832	,,	4·072	6·144	+·005	−·001	+·004	−·002
11636	9·3	21·178	6·802	·000	·000	·000	·000
11678	,,	16·394	12·513	+·003	·000	·000	−·002
11628	9·2	21·676	7·706	+·001	+·001	+·002	+·001
18414	,,	21·090	14·916	+·004	−·001	−·004	+·002
11659	,,	18·748	11·733	+·004	·000	+·001	−·001
11741	,,	11·326	11·745	−·002	·000	+·001	−·002
11776	,,	8·752	8·777	+·002	·000	+·002	+·001
11824	,,	4·993	13·095	+·002	+·001	+·007	−·003
11835	,,	3·889	8·776	+·002	+·003	−·002	+·002
11694	9·1	15·511	10·858	−·001	+·001	·000	−·001
8451	,,	15·457	16·695	−·002	+·001	−·003	+·004
11704	,,	14·745	7·359	−·002	+·001	+·001	·000
11766	,,	9·391	9·322	−·001	·000	−·001	·000
8500	,,	7·753	20·136	−·002	+·005	−·002	·000
8512	,,	5·576	16·948	−·002	−·003	·000	+·001
11819	,,	5·381	8·503	+·001	+·002	·000	−·003
8419	9·0	20·636	14·980	+·002	−·002	−·002	+·004

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Cat. No.	Mag.	x_1	y_1	δx	δy	(δx)	(δy)
8421	9·0	20·275	17·406	+·002	−·001	·000	+·001
11682	„	16·144	5·301	−·003	−·002	−·001	−·002
8453	„	15·130	15·584	+·004	+·001	+·002	+·001
11702	„	14·907	10·042	−·001	−·002	+·001	−·001
11707	„	14·637	10·054	−·001	−·002	+·003	−·003
8462	„	13·015	19·227	−·003	+·002	−·001	+·001
8472	„	11·450	15·765	·000	−·001	·000	·000
11748	„	10·657	11·269	+·001	·000	·000	−·001
11757	„	9·874	8·535	−·002	−·001	·000	+·003
8501	„	7·587	17·296	−·003	−·001	−·003	+·003
8519	8·9	4·717	17·185	−·001	·000	·000	−·002
11831	„	4·244	10·410	+·001	−·001	+·003	+·001
8482	8·8	10·859	17·055	−·002	+·001	·000	+·001
11830	„	4·360	6·075	−·002	−·002	+·002	−·005
8447	8·7	15·885	14·906	+·003	−·001	+·002	−·001
8502	„	7·444	19·762	+·001	−·003	+·005	+·001
11663	8·5	18·318	9·546	−·001	−·002	+·001	−·002
8456	„	14·273	16·791	+·003	+·002	·000	+·003
11717	„	13·662	13·464	−·002	−·004	+·002	−·005
11810	„	6·230	7·867	+·003	·000	−·001	·000
11648	8·3	20·059	10·055	+·002	·000	−·002	−·002
11701	„	14·879	6·942	+·003	−·001	+·002	+·003
11826	„	4·726	7·598	+·002	+·003	−·001	−·001
11809	8·1	6·575	13·449	−·002	−·001	·000	−·001
11755	8·0	9·913	4·570	+·003	−·005	·000	·000
11829	„	4·657	11·400	−·001	−·001	−·001	−·003
8513	7·7	5·180	19·606	+·001	−·001	+·001	−·001
8496	7·5	8·415	14·686	·000	+·001	·000	−·001
8518	7·0	4·752	15·754	+·002	−·001	−·002	+·002
8418	6·8	20·756	19·176	−·008	−·005	−·002	−·007
11715	4·4	Not measured					

5. The measures were made, according to the uniform practice at Oxford, in both the direct and the reversed positions of the plate. The non-circular form of the images on a photograph taken with a parabolic mirror makes it necessary to adopt some precise rule for setting on an image. The choice of such a rule involves a problem of no small difficulty and importance. The question presented itself in the course of reductions of photographs of Eros taken at Greenwich with the 30-inch reflector of the Thompson Equatorial * and a systematic change

* *Monthly Notices*, vol. lix. p. 399.

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of procedure is recorded. Unfortunately it is more easy to formulate a rule than to follow it, and unless an obvious point, as, for instance, the centre in the case of a disc, is chosen as the mark on which to point in measuring, it is exceedingly difficult to adhere to a consistent standard and to remain unaffected by subjective influences which vary with time and with the aspect under which an image is seen. In the present case the exposure of the reflector photograph was very long in comparison with that of the other plate, and therefore the images on it are apparently well developed—*i.e.* the fainter parts are not lost through under-exposure. The rule adopted was to set on that point of the axis of symmetry corresponding to the greatest width of the image. This point is not the focus for rays reflected at the centre of the mirror, but was chosen in the hope that it would give consistent results. and that it would not altogether fail even in the case of a star too faint to make a full impression. The drawback to this course lies in the fact that the maximum width of an image is by no means well marked, there being two ordinates of nearly equal length.* If, however, a setting is made on a point midway between these ordinates, there will be practically no distortion according to the geometrical theory, though the scale value will be that corresponding to a virtual focal length $f \sec v$, where f is the true focal length and $2v$ the angle subtended by the aperture of the mirror at the focus. Were it desired to find a scale value corresponding to the true focal length, it would be necessary to set on a point which is very near the extremity of the *complete* image in the direction of the centre of the field. But this is not possible, because this point lies outside the photographic image, the rays which should be incident on the centre of the mirror being intercepted by the plate itself.† In all this, however, it is supposed that the plate is accurately adjusted at the focus, and normal to the axis of the mirror. Now neither of these conditions is apparently fulfilled by the plate with which we have to deal. There are no point images at the centre of the plate ; on the contrary, the smallest image exceeds $20''$ in diameter. Nor is any marked symmetry of the field apparent about a centre which can be located with any certainty. Other causes, among which must be reckoned imperfections in the figure of the reflector, inequalities in the driving, variations of refraction, &c. conspire to produce images of a character very difficult to measure. On the whole the residuals appear more satisfactory than might have been anticipated.

6. In order to ascertain whether the plan of measurement just explained offered any advantage over bisection of the image a second series of measures was made by Mr. E. A. Gray, an observer possessing experience and skill in the measurement of astrographic plates and unbiassed by preconceived ideas as to the character of the images formed by a reflector. His measures

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* See vol. lxii. p. 356.

† Vol. lxii. p. 365.

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were treated in the same way as my own, and the residuals (δx) and (δy) are given in the seventh and eighth columns of the preceding table. The solution gave the following constants :

$$a = +0{\cdot}00119\,; \qquad d = +0{\cdot}00086$$
$$b = -0{\cdot}00066\,; \qquad e = +0{\cdot}00149$$
$$c = -0{\cdot}0316\,; \qquad f = -0{\cdot}0294$$

Between this solution and that of §4 there are differences

$$+0{\cdot}00015x + 0{\cdot}00017y - 0{\cdot}0034$$

and

$$+0{\cdot}00011x + 0{\cdot}00016y - 0{\cdot}0040$$

These expressions represent the systematic differences between my own and Mr. Gray's measures. It is evident that they do *not* correspond to a uniform change of scale value with symmetry about a point of the plate, as should be the case according to the way in which they have been obtained. Their approach to equality indicates rather a uniform strain, as it were, perpendicular to a line whose equation is approximately

$$x + y - 23 = 0$$

or very roughly a diagonal of the plate. No reason suggests itself for this peculiarity.

7. The sums of the four series of residuals irrespective of signs place in order of increasing accuracy δx, (δy), (δx), and δy, the sums being in fact ·119, ·108, ·092, ·085 respectively. It may be inferred that both coordinates can be measured with equal precision, and it cannot be said, at present, that either method of measuring possesses any advantage over the other. The probable discordance in a single coordinate may be taken to be $0''{\cdot}6$. This value and the evidence that a discordance ought very rarely to exceed $2''$ seem more satisfactory than might have been expected. For this reason the preceding table has been given in full. It must be remembered that these figures include not only the errors of the original reflector photograph, but also errors in the measures of the Oxford plate* and any faults possibly introduced in the double process of reproduction. On the other hand these figures apply only to a range of star-magnitude limited in both directions. Stars brighter than a certain magnitude, in this case about 7·0, cannot be measured satisfactorily. Thus the star *Leiden* 8418 (mag. 6·8) gives very bad results, while the star *Cambridge* 11715 = 52 *Cygni* (mag. 4·4) cannot be measured at all. For such stars the characteristic form of image is marred by photographic diffusion, by diffraction arising from the form of mounting of the plate carrier, and possibly in some cases by the nebulous character of the stars themselves. How far

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* The mean of two measures at Oxford has been found to have a probable error of $0''{\cdot}17$ (*Monthly Notices*, vol. lvii. p. 628). This is independent of errors in the position of an image.

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consistency can be secured in measuring fainter stars remains to be seen.

8. The measures already considered are those of stars whose catalogue positions are known, and which are therefore available for an independent reduction of Plate A. By means of them solutions have been obtained for the reduction of the plate according to either of the two methods of measurement employed. We are now in a position to extend the investigation in two directions. In the first place we may inquire in what way the errors of measured coordinates depend on the positions of the stars on the plate, and seek indications of possible distortion of a kind not compensated by the linear formulæ of reduction in which, it is important to remark, no attempt has been made to impose relations on the six constants. In the second place it is desirable to examine, if possible, any influence which the magnitude of a star may have on its estimated position. For the first object in view 45 stars were selected from those measured on Plate B by Mr. Mullis. They consist of nine fairly compact groups, each containing five stars, and situated roughly at the middle points of the sides, at the corners, and at the centre of the plate. The stars are fainter than those previously considered, and probably lie between the magnitudes 9·5 and 10·3. Series of measures were made (1) by myself, according to the method described in § 5; (2) by myself after an interval of some months by the same method, but with the plate placed in orientations 90° and 270°; (3) by Mr. Gray, who used the method of bisection as in the former series. Residuals were formed for each star by applying the solution of § 4 to the series (1) and (2), and the solution of § 6 to series (3). In the following table are given the means for each group under the respective numbers. The mean coordinates given in the first two columns are derived from measures of the first series. The means of discordances appended to the table have been obtained by adding the individual residuals, taken positively, and dividing the sum by 45, the number of the stars.

TABLE II.

		(1)		(2)		(3)	
x_1.	y_1.	δx.	δy.	δx.	δy.	δx.	δy.
		″	″	″	″	″	″
4·024	5·138	+1·8	+0·5	−0·4	−1·9	+1·0	−0·3
12·368	5·090	+0·2	−1·4	−0·9	−2·4	−0·2	−0·2
20·499	5·223	−0·7	+0·4	+0·9	−1·6	−0·2	+0·5
4·102	12·576	+0·6	+0·9	−1·8	−0·2	+1·5	−0·1
12·469	12·062	−0·1	−0·1	−0·1	−0·1	+0·6	−0·2
20·081	12·599	+0·8	+0·2	+1·3	−0·6	−0·8	+0·2
4·416	20·026	+0·7	+0·2	−2·4	+1·8	+1·0	+0·2
12·644	19·902	−1·4	+1·0	−1·7	+2·3	−0·8	+0·2
21·216	19·366	−1·5	−0·9	+1·8	−0·1	−1·2	−0·3
Means of discordances without regard to sign		0·85	0·62	1·25	1·23	0·91	0·52

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9. The "means of discordances" must be diminished by one-sixth if the general degree of accuracy is to be represented by probable errors. In this way it may be said that the probable error in x and y in series (1) and (3) is about 0″·6, a value previously found, though in both series the y-coordinates seem to be better determined than the x-coordinates. But in the second series of measures, though made with no less care than the first, the residuals are much worse. It is quite clear that the point aimed at in setting on an image was quite different in the two cases, and it seems to me impossible to secure uniformity. Hence the simpler method of bisection appears at present distinctly preferable. The mean group-residuals are in many cases so large that, although the general accuracy is poor, they indicate systematic and not accidental deviations. But no weight can be attached to the amount of such deviations, since the apparent absence of any connexion between the corresponding numbers in the first two series shows that they cannot be reproduced, being dependent on the temporary impression of the observer. In the third series the case may be different. The group-residuals in y are not so large that they need be regarded as otherwise than accidental. The x-residuals, on the other hand, seem to demand a change in the scale value of the abscissæ. This appears from the fact that the means of δx for small, intermediate, and large values of x are +1″·17, −0″·13, and −0″·73 respectively.

10. The stars whose measures have just been discussed lie, with the exception of one group, very near the edges of the plate, the area covered by which is about 2° square. Undoubtedly this increases the difficulty of making measures very considerably. In order to see whether images situated nearer the centre of the field and measured and reduced as before gave better results four additional groups were added. The results are shown in a form similar to the previous table.

Table III.

		(1)		(2)	
x_1	y_1	δx.	δy.	δx.	δy.
		″	″	″	″
8·383	8·894	−1·0	−1·2	−0·2	+1·0
16·630	8·635	+0·2	−1·7	0·0	−0·3
8·271	16·650	−1·1	+0·6	0·0	+0·8
17·392	16·138	+2·2	+0·3	−0·3	+0·2
Means of discordances without regard to sign :		1·20	1·00	0·64	0·82

Here the figures under (2) are comparable with those under (3) in the previous table, and show that the accuracy of bisection measures is of much the same order, whether the images are close to the edges or nearer the centre of the plate. The measures used in obtaining the figures of the first four columns above were made in the same manner as series (1) of the preceding paragraph, but at about the same date as series (2) of the same

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paragraph. The increased discordances are doubtless due to the fact that after the lapse of time the measures on which they depend are inconsistent with those on which was based the solution employed in the reduction.

11. The question as to how far accuracy depends on the magnitude of the stars whose positions are measured must now be considered, though the disproportion between the times of exposure of the two plates precludes a completely satisfactory answer. A selection of 45 of the faintest stars on Plate B was made, the distribution in nine groups of five stars each being similar to that employed in forming Table II. Measures were again made (1) by myself, (2) by Mr. Gray. The mean residuals are given under corresponding headings in Table IV., the first two columns of which contain the mean coordinates derived from my measures. The 'means of discordances' when compared with the corresponding figures under (1) and (3) in Table II. show that the accuracy attained is still less, as might indeed have been anticipated, than in the case of brighter stars. More especially is this the case with the x-measures obtained by the bisection method. Here again, as was noticed before, the measures seem to demand a different scale value, the mean residuals for the three distinct values of x being +1″·53, −0″·33 and −1″·90. The mean magnitude of the stars probably approaches 11·0. It is a little singular that the decreasing scale value with increasing faintness of the stars is a marked feature in the abscissæ but not in the ordinates. It has already been remarked (§ 9) that little weight can be attached to the residuals obtained by the method of measurement which I adopted. But in this case, if the displacements indicated by the residuals are plotted in a single diagram, they seem to suggest something of the nature of radial distortion. Here the measures might be better suited by *increased* scale values, a fact possibly due to an unconscious effort on the part of the observer to avoid the opposite effect.

TABLE IV.

		(1)		(2)	
x	y_1	δx.	δy.	δx.	δy.
		″	″	″	″
3·770	5·454	−0·6	−0·7	+1·3	+1·0
11·892	4·976	−0·3	−1·3	−0·6	+1·4
20·569	4·972	+0·2	−2·2	−1·0	+0·7
4·071	11·707	0·0	+0·2	+2·0	+0·4
11·716	11·804	−1·0	−0·8	+0·2	−1·0
20·306	11·842	+1·1	−1·2	−1·8	+0·6
4·162	19·970	−1·1	+0·2	+1·3	−1·1
11·996	19·625	−1·4	+1·3	−0·6	+0·4
20·404	19·126	−0·7	−0·2	−2·9	−0·6
Means of discordances without regard to sign:		0·93	1·08	1·57	0·90

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12. This note is obviously defective in two respects. The single plate used in the discussion is a long exposure photograph. Hence any deductions which have been made cannot be applied to a reflector photograph taken with a short exposure. But since plates of the latter description are among the material available for the *Eros* parallax determination, they will shortly be exposed to the most searching practical test, and the question of the accuracy of which they are capable must soon find an answer in this way. In the second place the shortness of the exposure of the refractor photograph has made it impossible to push the comparison beyond a certain range of star magnitude which falls short of the limit of the reflector plate. In particular it is not possible to assign the degree of accuracy with which the positions of nebular condensations can be measured. That this is a question of extreme importance is shown in the case of the nebula surrounding Nova *Persei*. But it may well be that it is not susceptible of a direct answer because the mere accuracy of measurement is complicated by the difficulty of choosing a definite point to measure. An illustration is afforded by the attempt to make such measures on the Nova *Persei* nebula at the Lick Observatory.* In this case the difficulty was so great that it was met by placing an artificial mark on the under side of the plate before the photograph was placed in the measuring machine. The fact that it may be necessary to obtain the desired data by measuring such a mark shows that the mere accuracy of measurement is of secondary importance.

13. When full allowance is made for limitations such as have been alluded to in the preceding paragraph the present note still contains results which may probably be considered typical of that large and important class of photographs which have been taken with long exposures by the aid of the reflector of short focal length. Among these results the following points may be summarised :—

(1) The positions of stars with magnitudes between 7·0 and 10·0 can be measured with a probable error of about 0″·6 in both coordinates. As compared with astrographic plates this degree of accuracy is very low and makes it impossible to trace with certainty, from a limited amount of material, anything of the nature of genuine systematic error. On the other hand, the accuracy is of about the same order as that of the A.G. catalogues (§§ 7 and 9).

(2) Measures made on images near the edges of the plate (say 1° from the centre of the field) are certainly not more inaccurate than those made on images lying about 30′ from the centre (§§ 8–10 and Tables II. and III.).

(3) As the magnitude of stars approaches 11·0 the order of accuracy is fairly maintained, but the measures point to scale

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* Lick Bulletin, No. 23.

values different from those determined from the brighter stars (§ 11 and Table IV.).

(4) Results are given in Tables I.–IV. for two distinct systems of measurement. Up to a certain point the two methods do not differ much in accuracy. The defect of the first (described in § 5) lies in the uncertainty with which measures can be reproduced after an interval or under different circumstances (§ 9 and Table II). The simple bisection method is much easier, but has the defect that it indicates a change of scale value with star magnitude, this anomaly being conspicuous in the abscissæ, but not in the ordinates (§ 11).

University Observatory, Oxford:
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William Herschel's observed Nebulous Regions, 52 in number, compared with Isaac Roberts' Photographs of the same Regions, taken simultaneously with the 20-inch reflector and the 5-inch Cooke lens. By Isaac Roberts, D.Sc., F.R.S.

William Herschel communicated a paper to the Royal Society which was published in the *Philosophical Transactions* in the year 1811, vol. 74, pp. 269 to 336, under the title of "The Construction of the Heavens"; and in a part of it is a section with the title: "Extensive Diffused Nebulosity" and "Observations of Nebulosities that have not been published before." Fifty-two regions in the sky are stated to be thus affected, and their coordinates of position and the approximate extent of the nebulosity are given in tabular form.

A century nearly has elapsed since these important statements were made, and astronomers still theorise and speculate concerning these nebulous regions in reliance upon the deservedly high eminence and conscientious care with which Herschel executed all his work. The aggregate extent of the diffused nebulosity in these fifty-two regions he estimated to cover about 151·7 square degrees, and he suggested that these represented only a small portion of the total areas in the sky that are similarly affected with nebulosity.

It occurred to me, several years ago, that it would be useful scientific work to photograph, with my 20-inch reflector, the fifty-two regions of diffused nebulosity which had been recorded by Herschel, and thus either verify, or correct, his observations in case of the absence of nebulosity. The photographs would also furnish data, that would be free from human bias and error, in the settlement of the questions, or inferences, which have been founded upon Herschel's records of these nebulous regions.

The work was commenced by me in 1896 and was completed